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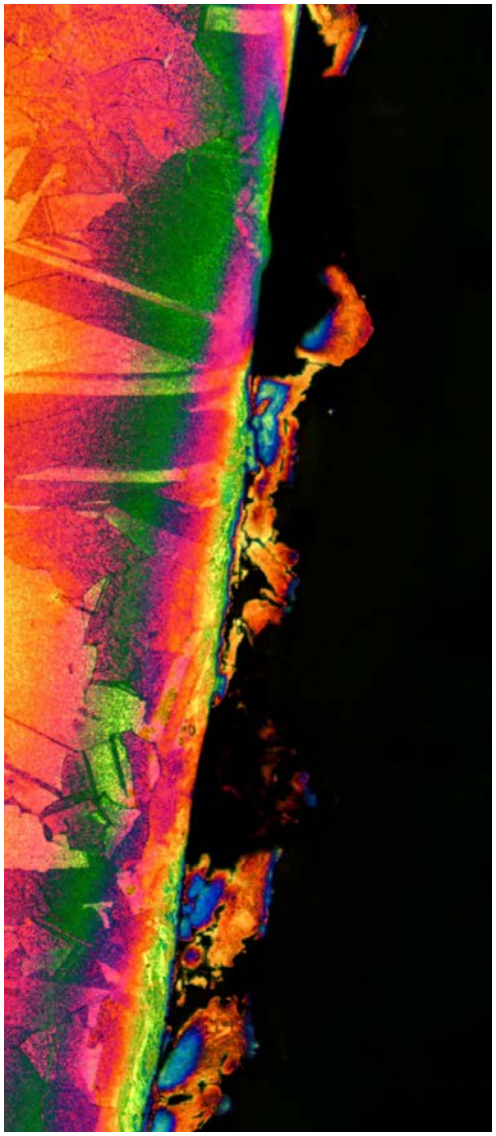

CLEANWIRX 207

Corrosion Exchange, LLC

Surface Decontamination: A Clean Route to a Corrosion-Free Environment and Asset Durability

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Costs associated with corrosion-induced maintenance and the replacement of public sector and industrial infrastructure is a staggering social and economic problem. Corrosion, which is not limited to region and thus a global problem, causes a heavy burden on the budgetary limitations of governments, and the profitability of businesses. Regardless of industry or application, standard approaches to corrosion remediation have proven ineffective and new long-term solutions for corrosion prevention are required.

The elemental cause in the process of corrosion and protective coatings deterioration is molecular contamination. This paper addresses the need that exists for a method that easily and quickly creates an amorphous oxide layer on the surface of a metal substrate while simultaneously removing contaminates. What is then offered is a solution: a patent-pending technology and process that provides a one-step solution to contaminant-driven corrosion.

The Costs of Corrosion

Starting from day one of service, industrial assets comprised of metal and concrete are perpetually degraded by the negative impacts of corrosion. The costs to maintain these assets can exceed the initial cost of the asset itself. In addition, corrosion reduces the effective service life of these assets, which further increases capital expenditures and could potentially lead to detrimental environmental and societal impact.

A comprehensive study on the cost of corrosion has determined that corrosion drains hundreds of billions of dollars from the U.S. economy alone, and the impact seriously threatens numerous business sectors. In 2001, a 900-page study, titled *Corrosion Costs and Preventive Strategies in the United States*, was completed by corrosion control engineering firm CC Technologies with the support of NACE International, and funding from the Federal Highway Administration. This exhaustive study analyzed and identified the costs of corrosion in 26 industrial sectors in which corrosion is known to exist and extrapolated the results to arrive at a nationwide estimate.

The study analyzed both direct and indirect costs of corrosion over the service lifecycles of relevant assets, such as the costs of corrosion as they relate to oil storage tanks. Direct costs of corrosion include all activities throughout the service life of a structure that are performed to prevent corrosion, repair its damage, and replace the structure. These activities include design, manufacturing, maintenance, inspection, repair, rehabilitation, and removal. Another large direct cost is the cost of downtime associated with maintenance activities due to the impacts of corrosion. Often the largest predictable direct cost comes from the decreased service life and corresponding increased depreciation of corroding assets.

Liability can also be an enormous cost. The costs associated with environmental catastrophes caused by corrosion-driven failures can be staggering, even to the point of bankrupting the owner of the failed asset.
The total direct cost of corrosion was determined by the study to be $276 billion per year, or approximately 3.2% of the U.S. gross domestic product (GDP) as of 1998. Adjusted for 2005 U.S. GDP estimates, annual direct costs increase to nearly $400 billion. Expanding industrialization trends in metallic composition and other factors are further accelerating the problem.

The reason why effective anti-corrosion solutions have been evasive is that they do not address the core causes of corrosion.

Internationally the problem is far worse due to inferior processes and substandard materials combined with challenging environmental factors. Reliable studies of the international problem are scarce, but estimates can be made based on the U.S. study. U.S. GDP is approximately 21% of the worldwide economy, which indicates a worldwide problem nearly five times greater than the U.S. However, the lower industrialization rate worldwide as compared to the U.S. suggests that cost of corrosion as a percent of GDP in lesser-developed countries is somewhat below that experienced in the U.S., although a more vulnerable international infrastructure would indicate higher rates of corrosion across similar assets. It is safe to say that the worldwide cost of corrosion far exceeds that of the U.S. alone.

Clearly the problem is massive and will continue to worsen unless a new, resolute approach to corrosion prevention is adopted.

For example, oil storage tanks experience significant deterioration from corrosion during their service lifecycles. Industrial oil tanks are typically taken out of service and treated with a standard anticorrosion process at least once every five to ten years.

The standard cleaning, drying, priming, painting, and inspection procedures for the internal lining of a 135-foot diameter tank will cost, on average, approximately $150,000. In addition, the cost of taking an industrial tank of this size out of service can easily run $5,000/day (and oftentimes much more), and total downtime can easily be 20 days. This means that it will cost roughly $250,000 per service ($150,000 + [20 days x $5,000/day]). Over an average 30-year service life for large oil tanks, three additional tank lining maintenance events is a reasonable expectation.

This oil tank scenario illustrates a typical experience in the never-ending effort to contain the negative effects of corrosion. The reason why effective solutions have been evasive is that they do not address the core causes of corrosion. Until the failure mechanism is recognized, standard preventative measures will continue to fail.

Pitfalls of Traditional Anti-Corrosion Measures

Standard responses to corrosion are little more than temporary stop-gap measures. Corrosion prevention measures include the use of various surface-blasting processes and anti-corrosion coating materials, with typical NACE standards of surface preparation requiring only that a defined visual standard be attained prior to the application of corrosion-resistant coatings.

However, these measures fail to address molecular causes of corrosion, and only delay the inevitable impact on serviceability and destruction of industrial assets. For example, under normal circumstances metal in contact with corrosive materials must be remediated and recoated with a protective coating on average every five to 10 years. This represents a significant, and perpetual, cost that only slows the negative impacts of corrosion. That is, it does not mitigate the corrosion.

When a coating has cured on an asset, it is put back into service. The substrate, however, will continue to be contaminated with molecular contaminants that were not removed during the blasting process, and so the deterioration process begins.

The standard anti-corrosion process follows a series of industry-defined stages. The process typically begins with careful cleaning of surfaces to a visual standard, such as those specified by NACE or SSPC. These standards of cleanliness result in a surface that when viewed without magnification, *appears* to be "free of all visible oil, grease, dust, dirt, mill scale, rust, coating, oxides, corrosion products, and other foreign matter."

The process generally consists of blasting with an abrasive to achieve a specified standard of visual cleanliness (*i.e.*, NACE 1, NACE 2, *etc*.) according to the requirements of the project and the specifications of the coating to be applied. Typically, the blasting abrasive will consist of silica sand or equivalent material that is dry, neutral pH, and free of dust, clay, or other foreign materials.

The reason why effective solutions have been evasive is that they do not address the core causes of corrosion. Until the failure mechanism is recognized, standard preventative measures will continue to fail.

After the blasting stage, it is usually necessary to control the environment of the surface to allow for effective application of the coating. This can become a cost-intensive process requiring industrial desiccant dryers and additional days of downtime.

Alternatively, the environment may need to be cooled, which reduces humidity. Dehumidification (DH) is costly and time consuming. In a typical maintenance scenario, DH can easily contribute 20% or more to required asset downtime, plus add up to 20% in additional process costs. The purpose of DH is to prevent rusting prior to coating. However, this does not prevent substrate corrosion, which can necessitate additional blasting. In fact, this happens quite frequently. It is not at all uncommon for the process to be repeated up to three or four times before surfaces may be properly coated.

One technique is to apply a holding primer immediately after blasting to keep the surface visually clean and rust-free prior to coating. The problem is that the primer coats over microbiologically influenced corrosion (MIC) and other ionic contaminants still present after abrasive blasting, although the surface appears visually clean at the point of coating. As a result, DH is often the most unpredictable and costly process in standard anti-corrosion maintenance.

Once surfaces are visually clean and existing environmental factors meet the specifications provided by the coatings manufacturer, an anti-corrosion coating may be applied. Coatings are typically sprayed onto surfaces. When the coating has cured the asset is put back into service. The substrate, however, will continue to be contaminated with molecular contaminants that were not removed during the blasting process, and the deterioration process begins as these contaminants are trapped on the surface by the protective coating.

Figure 1 illustrates how molecular contaminants remain on surfaces.

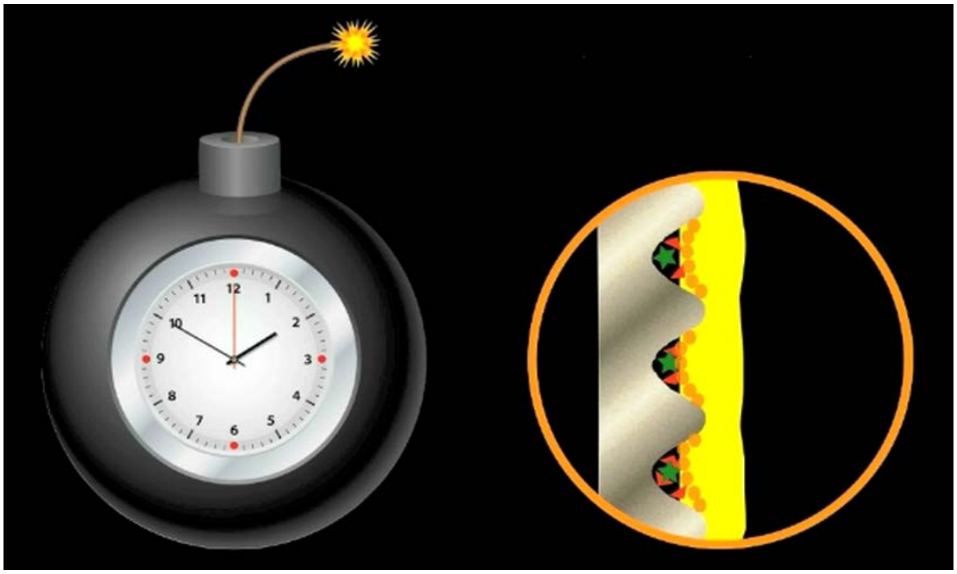

Figure 1: Shown is a depiction of the impact of coating over contaminants. As moisture begins to permeate the coating film, this acts as a food source—a catalyst—for the microbial contaminants and accelerates the corrosion process, and it becomes just a matter of time before deterioration begins, causing the asset to be taken off-line for maintenance. Source: Corrosion Exchange LLC

Core Causes of Corrosion

A key accelerant of aggressive corrosion is the result of microbial surface contaminants, either because they directly attack substrates or cause premature coatings failure. MIC is caused by sulfate-reducing bacteria, acid-producing bacteria, and other contaminants that greatly increase osmotic blistering, which is the principal cause of coating failure.

Visual standards of cleanliness do nothing to assure the removal of these microbial contaminants, which is a significant cause of coatings failures.

Bacteria settle next to the substrate and produce acids and other ionic compounds that corrode the steel and cannot be removed using abrasive blasting alone. Unless these contaminants are effectively removed, surface coatings trap contaminants within the film. As moisture begins to permeate the coating film, these particles stimulate the activation of microbial contaminants and starts the corrosion process. As the surface corrodes, moisture vapor begins building pressure on the coating. This results in premature failure of the coating.

Another major factor in the reduction of coating life is the presence of soluble salts—chlorides—on steel substrates. The detrimental effect of these contaminants on coating performance has been discussed in coating-related literature for nearly 40 years. Soluble salts present on a substrate initiate coating failure and substrate corrosion through an osmotic blistering process.

For example, a typical mechanism of failure on a dry-blasted chloride contaminated steel substrate occurs as ferrous chloride is immediately formed whenever steel (iron) and chlorides come in contact. The reaction is very

corrosive to steel substrates. Upon exposure to air, ferrous chloride quickly oxidizes to form ferric chloride, a soluble salt with natural affinity for available moisture (hygroscopic salt). Residual ferric or ferrous chloride contaminants on the substrate accumulate moisture from the air, resulting in the formation of a concentrated iron chloride solution on the surface of the steel. The iron ions, chloride ions, and water comprise an electrolytic solution that drives an electrochemical corrosion reaction. Coatings applied over the contaminated steel substrate will fail in a short period of time due to a concentrated iron chloride solution on the substrate. This draws water through the porous coating membrane by osmosis, which in turn activates corrosion cells and promotes premature coating failure.

Visual standards of cleanliness do nothing to assure the removal of these microbial contaminants, which is a significant cause of coatings failures. The rate of coating failure due to this osmotic blistering is dependent on the service environment, coating thickness, and coating porosity; but more importantly it is dependent on the purity level of substrate cleanliness at the time of base coat application.

"Intergranular contaminants such as sulfides and chlorinated hydrocarbons are more elusive to quantify since they are more difficult to remove. There is no generally accepted standard for either chloride, sulfate, or sulfide contaminant levels under coating and lining systems."—Lou Vincent, "Decontamination of Metal Substrates," 1998.

Due to the hygroscopic nature of ferric salts, controlled temperature and humidity conditions are not effective in preventing a monomolecular layer of water from collecting on salt-contaminated substrate surfaces. These contaminants must be eliminated to avoid coating over a microscopic moisture accumulation. While the mechanism of coating failure due to contamination of substrates by soluble salts has been understood and thoroughly documented, cost-effective solutions have not materialized. Blast cleaning specifications have primarily focused on visual standards and have not fully addressed removal of non-visible surface contaminants.

Metal Surface Hygiene

The level of substrate cleanliness required for optimum coating adhesion varies significantly depending on the service environment and the characteristics of the selected coatings, although in practice the cleaner the substrate the greater the resistance to coating disbondment.

To maximize adhesion and impermeability, coatings must perfectly and permanently match the surface and pores of the surface. The distance between the surface of the substrate and the coating should be as small as possible, with no microcontamination between substrate and coating to prevent perfect adhesion. Reliable, fail-safe surface decontamination in the field is therefore critical to creating an optimally receptive surface for coating.

Sulfides are extremely hygroscopic, ionically charged, difficult to remove, and ubiquitous in steel and other metals. In recycled metal, the presence of sulfides greatly accelerates corrosion, with hydrogen blistering associated with "dirty steel," or steel with a high sulfur composition. Optimal surface preparation is, in essence, a matter of metal hygiene. Removing sulfide and sulfate contaminants logically increases resistance to cracking.

Kits are available to test for chlorides prior to coating, but not for sulfides (which are insoluble). Current field testing is purely qualitative, it does not give an accurate quantitative measure, as chlorides beneath iron sulfide films are

undetectable. Accurate testing for intragranular contaminants requires SEM and EDS analysis. Therefore, testing is unlikely to reveal the true state of metal hygiene.

Salt and rust removal products only remove soluble salts; they cannot remove sulfides or chlorides hidden beneath sulfide films. Indeed, it is difficult even to detect such hidden salts.

> *"Iron sulfide is insoluble; therefore, water cleaning is not possible. Sulfides penetrate the intergranular crevices in metal substrate and are difficult to remove."—Lou Vincent, "Decontamination of Metal Substrates," 1998.*

The wholesale removal of sulfides and other microcontaminants is necessary to promote maximum coating adhesion and consistent contact at the coating/substrate interface. A metal decontamination product developed by Corrosion Exchange LLC removes ionic and highly hygroscopic microcontaminants (*i.e.*, sulfides, sulfate chlorides, nitrates, and microbial byproducts) from metal surfaces by penetrating the sulfide film, breaking the sulfide bonds, and rinsing away microcontaminant detritus to ensure more reliable and complete surface preparation outcomes.

The technology behind the product, CleanWirx 207, entails a surface preparation process that eliminates the underlying causes of coatings failures and thereby prevents corrosion. CleanWirx 207 prepares surfaces at a molecular level by eliminating microscopic levels of corrosive elements that are a major cause of coatings failure. The result is that subsequent surface coatings can withstand extremely hostile environments and remain durable and maintenance-free, thereby reducing future maintenance and refinishing cycles.

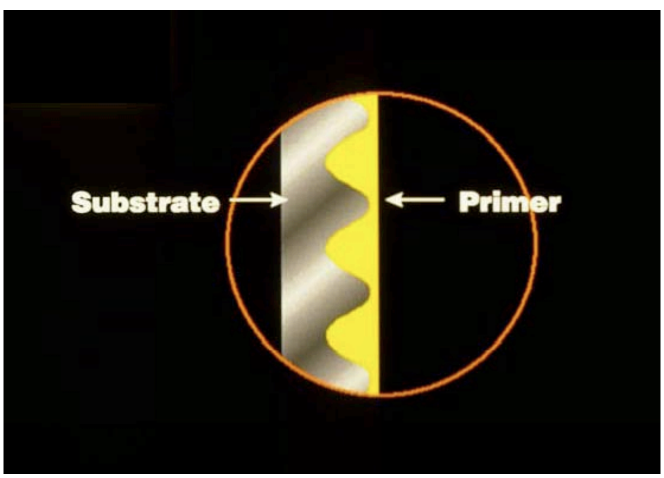

Figure 2: Corrosion Exchange has developed a patented technology and process that provides an effective solution to contaminant-driven corrosion. This image depicts how CleanWirx 207 allows protective coatings to bond to a truly decontaminated surface. Source: Corrosion Exchange LLC

Decontamination Process

The need for a method and formulation to prepare surfaces of materials such as concrete and metals to remove contaminates and prevent degradation of both coatings and the underlying material through oxidation, or other chemical processes is what lead to the development of CleanWirx 207.

The product is a surface decontamination treatment that achieves a *zero-detectable* level of ionic contaminants on surfaces, well beyond the accepted visual standard, for a microscopically clean surface in a single step. This "beyond visual" level of decontamination eliminates contaminants that cause interference with coating adhesion. This facilitates an intimate bond at the coating-to-substrate interface. The result is that coatings become far more durable and their corrosion resistance is enhanced considerably.

The CleanWirx 207 technology decontaminates surfaces using a proprietary process and a patent-pending chemical neutralization agent. The result is a reaction of water and non-water-soluble ionic contaminants. This alters the molecular structure on the treated surface, which in turn removes MIC-based and other ionic contaminates. This is followed by a clean water rinse to prepare surfaces for the application of a coating. The decontaminated coated surfaces will have an inherent resistance against corrosion, which significantly enhances the life expectancy of the coating.

The greatest cause of corrosion on properly coated surfaces is the existence of molecular contaminants.

The product may be used with small-footprint portable wet abrasive vapor blast (WAVB) units. A dilute mixture is added to the blast tank to simultaneously decontaminate during blast cleaning. The resulting surface hygiene requires no additional processes or products (*i.e.*, salt removers, inhibitors, dehumidification, rust removers) before coating. One of the benefits of the WAVB method is that is consumes significantly less energy than ultra-high-pressure water blast technology. It also requires minimal operator training due to inherently lower safety risks. However, the product can also be deposited on a metal substrate by wet abrasive blasting, high-pressure water blasting, or ultra-high-pressure water blasting. After blasting, the metal surface is dried until a passivated amorphous oxide layer integrates into the outer surface of the metal substrate.

CleanWirx 207 integrates seamlessly with standard anti-corrosion processes and coatings. During standard, anti-corrosion maintenance events the product is easy to implement and can often be applied by the maintenance contractor. It is applied right after standard surface blasting, and before application of an anti-corrosion coating; it's also environmentally benign and has no VOCs (volatile organic compounds).

A clear benefit of CleanWirx 207 is that once the process is complete, uncoated surfaces will resist corrosion for an extended period. This means that if it is applied directly after blasting, the DH step is eliminated. Since it is at the DH step that process repeats occur (*i.e.*, re-blasting), the introduction of the product into the maintenance process can substantially reduce both cost and downtime.

CleanWirx 207 is suitable in high-corrosion applications such as tank farms, oil and gas pipelines, bulk rail and road tank cars and materials carriers, general industrial piping, chemical companies and refineries, and marine applications, to name but a few.

Figure 3. Shown are metal pipes coated with the CleanWirx 207 surface preparation system. The piping included 12" pipe and drums located adjacent to four brine pits. *This photograph was taken in October 2005, ten years after the product was applied.* As seen, they show no corrosion or coatings deterioration after ten years of maintenance-free durability. Source: Corrosion Exchange LLC

Executive Summary

Corrosion is a never-ending problem that is projected to only get worse. As economies expand so does the infrastructure that is susceptible to corrosion-driven depreciation. This is occurring at an accelerating rate as more nations become more developed. Another factor that is significantly aggravating the problem is that more and more metals are being recycled. This is resulting in unintentional mixtures of dissimilar metals, which radically accelerates the corrosive process. As older assets are replaced with these recycled materials an ever-expanding portion of the infrastructure consists of highly corrosion-susceptible metals. Furthermore, nearly thirty years ago the use of lead-based coatings was banned for environmental reasons. This eliminated one of the best protections against corrosion. Taken together these factors will only further exacerbate the problem.

The CleanWirx 207 anti-corrosion solution allows owners to substantially avoid a range of costs that are typically experienced with standard corrosion prevention measures. These cost savings fall into three categories: 1) lower cost of treatment, 2) less downtime, and 3) longer service lifetimes resulting in lower depreciation.

CleanWirx 207 can lower the cost of standard corrosion maintenance by eliminating dehumidification and the need to re-blast. In addition, CleanWirx 207 may trim certain portions of the labor cost and will typically reduce the direct costs of corrosion service events by approximately 10%-15%. CleanWirx 207 will also speed up maintenance events, resulting in less downtime. For example, in a typical corrosion maintenance operation it will reduce average downtime by 20%-40% of the downtime associated with an internal tank lining service event.

In addition to these maintenance savings, CleanWirx 207 will also extend the usable life of the asset. While it will require decades to fully gauge the increased service of CleanWirx 207 treated assets, experiences so far indicate that CleanWirx 207 will significantly extend usable service life. It is entirely viable to experience an increase in asset lifecycle of 30% to 50%, although this only applies to an asset's corrosion-impacted service life (vs. accidents, forces of nature, land use, *etc*.). Actual field results indicate that CleanWirx 207 will provide significant benefits in asset-management cost and extended service lifecycle.

Standard methods of blasting and coating are unable to effectively mitigate the problem, and only serve to delay the inevitable. The need for an entirely new approach has never been greater. The most viable solution available is to stop corrosion at its source. The greatest cause of corrosion on properly coated surfaces is the existence of molecular contaminants. By effectively removing these contaminants from surfaces, coatings failures can be largely prevented; resulting in significantly reduced costs and enhanced asset service life cycles. CleanWirx 207 provides an effective approach to molecular decontamination and asset durability.

For technical presentations, case studies, and analysis of how CleanWirx 207 *can enhance your anti-corrosion maintenance program contact:*

Corrosion Exchange, LLC
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About the author: In 1991 Loren Hatle identified a previously overlooked and preeminent cause of corrosion and since then he has continued his investigation and made may revolutionary discoveries.

Motivated by his discovery, Mr. Hatle began research on an entirely new method of metal decontamination designed to address the chronic problem of premature coating failure. That research has resulted in the creation of a surprisingly simple and amazingly effective product. CleanWirx 207 revolutionizes metal surface preparation and protection processes where corrosion is extremely difficult to manage.